Studies of Local magnetism and Local Structure in $La_{2-x}Sr_xCuO_4$

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We have presented the results of studies of magnetic ordering and correlation in $La_{2-x}Sr_xCuO_4$ via muon spin rotation (μSR) and DC magnetization. Evidence for a local structural distortion at the Sr dopant site was also presented. We briefly summarize some of these results in the following.

Early zero-applied-field μSR results demonstrated unambiguously the occurrence of magnetic order in La_2CuO_4 at temperatures below approximately 250 K [1]. It was also determined that the ordered magnetic state is destroyed quickly by Sr doping, with the ordering temperature being reduced to 12 K for x=0.02 and below 6 K for x=0.05. The internal magnetic field probed by the muon precession frequency remains approximately a constant up to x=0.02 despite the rapid suppression of the ordering temperature, suggesting that the magnetic moment on Cu atoms is not reduced appreciably [2]. The suppression of magnetic order by Sr doping is likely a result of a weakening of the effective interaction. For superconducting samples with x = 0.07, x = 0.10, and an x=0.15 sample with T_c=35 K, an observed rapid muon depolarization rate indicates the existence of strong magnetic correlations with an electronic origin. The strength of this magnetic correlation, as measured by the internal field probed by the muons, decreases as T_c increases. In an x=0.15 sample with T_c=39 K, the internal field becomes vanishingly small. At the present time it is not clear whether these magnetic correlations, which are observed at low temperatures (T < 4 K), are related to the superconducting pairing mechanism.

A peak-like anomaly appears.in the temperature-dependent DC magnetization at the onset of antiferromagntic ordering in undoped and lightly doped La_2CuO_4. A similar anomaly was, however, not observed for $x \geq 0.02$ even though a magnetically ordered state was suggested by local probes such as μSR and NQR (4). It is generally speculated that a spin-glass state may exist in the region for $0.05 \geq x \geq 0.02$, bridging the AFM and superconducting phases. During the effort to study the nature of the magnetic state in the spin glass region, we observed a cusp-like anomaly at a temperature $T_f(x)$, similar to the kind expected from a spin-glass transition, in DC magnetization measurements performed on vacuum-annealed x=0.02 and 0.03 samples [4]. In addition, a similar anomaly was clearly observed at T_f in the temperature dependence of the amplitude of an electron spin resonance (ESR) signal also measured in vacuum-annealed samples. There are reasons to believe that this ESR signal is due to spins that give rise to the low temperature magnetic phase measured via NMR, μSR and DC magnetization, with general agreement amongst the values of T_f determined by the four methods . However, the measured temperature dependence of the ESR linewidth and the resonance field do not follow the expected behavior of the usual spin glass system.

Attention has been focused on the homogeneity of the $La_{2-x}Sr_xCuO_4$ material. As an effort to understand the local

structural effect of Sr doping, a series of x-ray absorption measurements at the Sr K-edge have been made on various $La_{2-x}Sr_xCuO_4$ materials. Our Sr x-ray absorption near-edge structure (XANES) results suggest a local structural distortion at the Sr site when a La is replaced by a Sr [5]. The structural distortion leads to a nearly empty apical oxygen site near the Sr dopant in samples prepared under normal conditions. Accompanied with this, it was proposed that an interstitial defect oxygen is trapped near each Sr atom at low doping level. The defect oxygen is more tightly bound in the structure than the apical oxygen. The defect oxygen may serve as a mechanism for hole doping similar to the hole doping by excess oxygen in oxygen-enriched La_2CuO_{4+y}. Evidence for a local structural distortion in the $La_{2-x}Ba_xCuO_4$ compounds was also observed.

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